Development and evaluation of a classroom activity to promote integration of engineering with other academic disciplines

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Abstract—This innovative practice full paper assesses an engineering classroom activity featuring integration. Engineers are a part of a broad community that contributes to the rapidly changing and growing technological innovations demanding contributions from multiple branches of engineering and academic disciplines. Therefore, the ability to recognize and understand interdisciplinary connections between engineering and all academic disciplines is critical for students' academic success and professional preparedness. There is a need to develop novel classroom activities that enable students to recognize such connections. To that end, the objective of this research was to (a) develop a hands-on, student-led, classroom activity that can help students make interdisciplinary connections and (b) assess the impact of the activity on students' perception about the interdisciplinary connections. A two-session classroom activity was designed in which students worked in teams and mapped different areas of study within mechanical engineering (ME) as well as seven non-engineering academic disciplines (NEAD) to real world, complex technological innovations such as virtual reality goggles, drones, and 3D printers. During the activity, active learning tools such as concept maps and jigsaw method were utilized. A total of 49 sophomore, ME students from a four-year university participated in the activity and associated assessments. All students participated in two surveys administered at the beginning and end of the activity to rate their motivation and excitement towards ME areas of study and seven NEAD, and their believed level of importance and relevance of the ME areas of study and NEAD to product development. The quantitative data analysis showed statistically significant increases in multiple survey items, showing an overall success of the activity in increasing students' awareness of connections within and outside of engineering. The lack of changes in some survey items guide us towards areas and topics that need improvement to teach the relevance and integration of all disciplines to students. In future, these quantitative findings will be coupled with qualitative data from students' retrospective reflection on the activity, student focus group, faculty interviews, student learning assessments and students' concept maps to optimize the activity, assess student learning and finalize assessment instruments so the activity can be widely adopted by educators.

Keywords—Active learning, Engineering design, Integration, Interdisciplinary, Curricular-design

I. Introduction

The ability to identify and understand interdisciplinary connections between technical and non-technical disciplines is critical to student success in the academic and professional world. Preeminent accreditation boards recognize and require evidence of student outcomes in these areas. The Accreditation Board for Engineering and Technology (ABET) outlines seven student outcomes whose attainment is necessary to prepare graduates for success in their chosen profession. Objective two, "[an] ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors" [1] and objective four, "[an] ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts" [1] both necessitate an interdisciplinary mindset.

Evidence suggests that undergraduate instructors are interested in integrating multiple disciplines in their courses, and several universities are incorporating such efforts in their curricula [2]. Much of these efforts are contained in long-term design courses and are not easily adaptable for shorter sessions [3]-[7]. Additionally, there are logistical challenges related to staffing, scheduling, and course integrations across different disciplines at a university [2]. For example, multidisciplinary student teams can help strengthen interdisciplinary connections. However, for this to work, multiple departments within a university need to allocate course time for the combined group activity, which is not trivial [2]. There is a need for adaptable, student-led, classroom activities that help students recognize connections between academic disciplines within the curricular and university constraints.

Thus, the objective of this research was to develop and assess a hands-on, student led classroom activity that helps students identify interdisciplinary connections and better understand the role of engineers and non-engineering professionals in product development. The activity is designed to be adapted into design and non-design courses and can be executed in as little as 150 minutes spanned over at least two sessions. The activity is flexible and can be adjusted to be completed in less than 150 minutes as long as the duration spans for two sessions or more. The activity also has sufficient scope to be lengthened if an educator decides to do so. In addition to designing the activity it was also critical to develop assessment instruments to evaluate the activity's efficacy. For the scope of this paper, the efficacy of the activity was defined as the ability to positively impact students' awareness, excitement, or perception of the relevance of various fields of study within mechanical engineering as well as of non-engineering academic disciplines. Although not included in this paper, assessment instruments and accompanying rubrics were also developed to measure student learning. This is a part of the future work and will be shared in a subsequent publication. For this work, the areas of study considered within mechanical engineering (ME) were: dynamics & controls, mechanics & materials, thermal fluid systems, manufacturing & design, and programming & computer aided design. Similarly, for this study, the non-engineering academic disciplines (NEAD) considered were: business, humanities, natural science, applied science, mathematics, social science, and political science. These lists were curated by reviewing the websites of several four-year ABET accredited universities and education sites [8]–[13].

Several initiatives have been undertaken to increase student engagement with interdisciplinary projects [3]-[7]. Students at the University of San Diego enrolled in a project-based drone design course that brought together students from the School of Engineering and School of Peace. Topics including "Disciplinarity, technology, and social change" were engaged in class discussion and applied to drone design [7]. Similarly, at two French universities, students participated in a biomechanical engineering course focused on the design of prosthetic feet for children [5]. While these courses are largely effective, they focus on the integration of a select number of academic disciplines with engineering. Additionally, they are often semester-long projects that are not as easily adapted to existing design courses as the activity presented here.

II. Research Questions

The primary research question for this work is the following:

How does the activity impact early college ME students'

- excitement about ME areas of study
- perception of the relevance of ME areas of study towards product development
- perception of the relevance of NAED towards product development
- perception of the impact of NAED on their formation as a mechanical engineer
- understanding of the role of a mechanical engineer

III. Class Activity Description

The activity was held over two 75-minute in-class sessions with 2 survey administrations: one before the activity and one at the conclusion. In addition to the survey administrations, which were primarily done to evaluate students' attitudinal factors, like excitement and perception, three student learning assessments were implemented as well. The goal of the learning assessments was to evaluate student learning. The entire activity and accompanying learning assessment administration can be broken into 9 steps.

Step 1: (pre-session 1) Collect student learning assessment #1. In this assessment students reflected on their current knowledge of innovative products and their use.

Step 2: (pre-session 1) Assign student teams a specific, real-world, complex, technological product. A total of eight products were selected for this iteration of the activity: Honda Smart Home, virtual reality googles, pacemaker, ventilator, brain controlled robotic arm, geothermal heat pump, SAEBO stroke recovery device, and electrical vertical take-off and landing aircraft [14]–[21].

Step 3: (pre-session 1) Collect responses to questions related to the assigned product. Each student was asked to research the assigned product to understand its basic conceptual functionality and use. To guide their investigation and to document student learning, the following questions were asked:

- Did you already know about this product and its use?
- What are the primary working principles of the product assigned to your team? (Ex: 3D printer working principles – heating and melting thermoplastic, using a computer-controlled system to move the plate and printer head up and down, software converting 3D solid file to format that printer can interpret, etc.)
- What is the basic operation of the product assigned to your team? (Ex: 3D printer operation – (1) save 3D solid file (2) select position, orientation, and print settings (3) transfer file to 3D printer (4) printer head heats (5) printer head calibrates by touching bed etc.)
- What are some common, uncommon, and/or creative applications of the product assigned to your team?

Students were asked to answer the above questions through Google© Forms before attending the first session.

Step 4: (In-class session 1) Student teams worked in class to decompose the assigned product. To assist with the decomposition, students were asked to follow one of the two decomposition approaches:

- Decompose based on working principles and subsystems (e.g. control and electronics, material selection, safety, aesthetics etc.)

- Decompose based on sequence of user-action and operation (e.g. adjust straps of goggles, fit the goggles on head, turn on headset, check volume, etc.)

Step 5: (In-class session 1) Students reviewed a provided list of common mechanical engineering areas of study and respective definitions. The following is a sample definition for mechanics & materials:

- Area of study concerned with the "Study of deformation, fracture, fatigue, and failure of solids at different time and length scales (from atoms to planets) through advanced analytical, computational, and experimental techniques"
- Industry applications include structures, machinery, biomechanics, deformation and stress analysis
- Example course(s): ME 2103 Mechanics of Materials, ME 3300 Material Science I, ME 3402 Solid Mechanics & Design I, ME 3333 Manufacturing Engineering.

Students used a free, limited, online concept mapping software called Creately© to generate concept maps [22]. Concept mapping is a popular tool used by educators to help students identify and understand relationships between topics. According to Hartsell, concept mapping supports constructivist learning methods and allows students to use their personal experiences to draw connections in an "Authentic setting" [23]. Students were instructed to map each ME area of study to one or more of the decomposed parts of the product (step 4). Students were also instructed to describe how each area of study was connected to the specific decomposed part. A snapshot of a sample student-generated mechanical engineering areas of study concept map is shown in Figure 1. The decomposed step is shown in the blue rectangular boxes. The area of study mapped is shown in orange. A description of how the area of study is connected to the decomposed part is presented in the grey boxes. Student teams submitted their concept maps via Blackboard at the end of the session.

Step 6: (in-class session 1) Students completed student learning assessment #2. In this assessment students summarized what they considered the purpose of the activity to be and some main takeaways.

Step 7: (pre-session 2) Each student from a team was assigned 2-3 non-engineering academic discipline (NEAD) to investigate before the next session. For this part of the activity, the jigsaw method was used [24]. The members of a team were assigned different NEAD to research and investigate. Students were expected to return to class as "experts" for their assigned NEAD. Students were provided a full list of NEAD and a brief, general definition. The following is a sample definition for social science:

- Social science is the study of current and past societies. The field works to understand how a society functions at all levels-individuals, families, communities, governments, and cultures. Social scientists try to find answers to real-world problems like crime, child abandonment, hunger, education, ethics, social injustice etc. They also try to answer questions like why we dress, talk, shop, and act like we do.
- Common subject areas: Anthropology, education, geography, law, psychology, sociology, ethics.

Step 8: (in-class session 2) Students began session 2 by grouping with students from other teams who were assigned the same NEAD. For example, all students assigned business as the NEAD were grouped. During this "experts" group meeting, all students shared their findings from their independent research.

Step 9: (in-class session 2) All students returned to their original teams ensuring that each team had "experts" from all NEAD. Students then mapped each NEAD to the decomposed product (same as the one used in step 5). In addition to connecting the NEAD, students were asked to explain how the NEAD related to the decomposed part of the product. A snapshot from a student-generated NEAD concept map is shown in Figure 2. The decomposed subsystems and working principles are displayed in blue and green respectively. The mapped NEAD is shown in dark green. The explanation for the mapping is displayed in blue outlined boxes connecting the NEAD to the working principle.

Step 10: (post-activity). Students submitted their completed concept maps and a reflective essay, student learning assessment #3. In the essay, they reflected on changes in their learning, motivation, and perceptions about ME areas of study and NEAD. Examples of complete concept maps are available for review upon request.

IV. METHOD: ACTIVITY EVALUATION

A. Data Collection

The sample of this study consisted of 49 ME sophomore students at one ABET accredited university who were enrolled in a core, required course titled: ME Analysis and Design during Fall 2020. The course activity was executed online due to the university's response to the COVID-19 pandemic.

Two surveys were administered. The first survey was conducted prior to the beginning of the activity and measured students' excitement and perceptions and understanding of the role of mechanical engineer before being introduced to the activity. The second survey was conducted at the completion of the activity and measured students' excitement and perceptions and understanding of the role of a mechanical engineer after completing the activity. Both surveys contained many of the same survey items to facilitate a pre-post analysis. Table I summarizes the relevant subset of the survey items and their administration.

Google© forms was used to administer the survey and collect raw data. The link was shared via email, as well as posted on Blackboard, and the students were required to complete the surveys at the associated times.

A mixed methods approach was used to develop the surveys. The surveys consisted of questions that required Likert-scale responses as well as questions that were open-ended [25]. Open-ended responses will be analyzed in future. A mixed methods approach encouraged students to think both critically and creatively about their experiences, while helping to minimize bias. The following is an example of a Likert style survey item: "According to you, how relevant are the following areas of study to the successful development, operation, and use of the products you listed previously? (1: Not relevant at all – 5: Very relevant) [Dynamics and Controls]". The following is an example of an open-ended survey item: "Share what makes some mechanical engineering areas of study relevant to the development, operation, and use of products (e.g. the products you listed)".

B. *Data Analysis*

Quantitative data was analyzed. Background information pertaining to selection of a minor and/or concentration, was recorded. Likert survey responses were assigned a numerical value between 1 and 5. For example, for the product relevance question, Q3, 1, 2, 3, 4, and 5 were assigned to the response "Not relevant at all", "Barely relevant", "Neutral or indifferent", "Relevant", and "Very relevant" respectively. Similarly, for the excitement questions, 1, 2, 3, 4 and 5 were assigned to 1 for "Not excited at all", "Barley excited", "Neutral or indifferent", "Excited", and "Very excited" respectively. For the question related to the students' formation as a mechanical engineer, Q4, a scale from 1 to 4 was used. The numbers 1, 2, 3 and 4 were assigned to the "No", "Maybe", "Slightly", and "Yes" respectively. For the question related to the students' confidence, Q5, a scale of 1 to 7 was used and students directly chose a numerical answer. The number 1 was defined as "Not at all true of me" and 7 was defined as "Very true of me".

To determine statistical significance of any changes in quantitative data sets, the Wilcoxon signed rank sum (WSRS) test was used. WSRS is a non-parametric test of statistical significance in the median difference between two observations [26]. Medians, means, and standard deviations were computed. The areas of study and academic disciplines with the highest median scores were considered most exciting/relevant. The areas of study and academic disciplines with the lowest median scores were considered least exciting/relevant. All statistical analysis was conducted using Excel and SPSS [27]. The medians and means from the pre- and post-surveys were recorded and compared.

TABLE I. ASSESSMENT ADMINISTRATION

Question #	Assessment Item	First Survey	Second Survey
Q1	How excited are you to take courses in the following areas of study in your upcoming semesters? (Ex. Thermodynamics)	X	X
Q2	According to you, how relevant are the following areas of study to the successful development, operation and and use of the products you listed previously? (Ex. Thermodynamics)	X	X
Q3	According to you, how relevant are the following academic disciplines to the successful development, operation and use of the products you listed previously? (Post: General Product)	X	X
Q4	According to you, will the following academic disciplines have any impact on your formation as a Mechanical Engineer?	X	X
Q5	I have a clear understanding of what a mechanical engineer does.	X	X

V. RESULTS

A. *Mechanical Engineering Areas of Study: Excitement*

Students were most excited to take courses in dynamics, mechanics & materials, manufacturing and design and programming (median = 4) before and after the activity. Students were least excited to take courses in thermal fluid systems (TFS) (median = 3) before and after the activity. These results are summarized in Table II.

TABLE II. HOW EXCITED ARE YOU TO TAKE COURSES IN THE FOLLOWING AREAS OF STUDY IN YOUR UPCOMING SEMESTERS?

Survey Item	Pre		Post		P-value	Significance
	Mean	*Median*	*Mean*	*Median*		
Dynamics	4.00	4	3.82	4	0.24	0
Mechanics & Materials	3.78	4	3.82	4	0.98	0
Thermal Fluid Systems	3.14	3	3.18	3	0.84	0
Manufacturing & Design	3.88	4	3.93	4	0.89	0
Programming& Computer Aided Design	3.51	4	3.68	4	0.48	0

B. *Mechanical Engineering Areas of Study: Relevance*

Students felt that dynamics, mechanics & materials, and manufacturing & design were the most relevant (highest median score, 5) to product development before and after the activity. Students felt that thermal fluid systems was the least relevant (lowest median score, 4) to product development before and after the activity. Students felt that programming and computer aided design was also the least relevant to product development after the activity. The relevance of dynamics and thermal fluid systems increased (p-value 0.065, 0.011 respectively). The relevance of programming & computer aided design decreased (p-value 0.015). These results are summarized in Table III.

TABLE III. ACCORDING TO YOU, HOW RELEVANT ARE THE FOLLOWING AREAS OF STUDY TO THE SUCCESSFUL DEVELOPMENT, OPERATION AND USE OF THE PRODUCTS YOU LISTED PREVIOUSLY?

Survey Item	Pre		Post		P-value	Significance
	Mean	*Median*	*Mean*	*Median*		
Dynamics	4.35	5	4.61	5	0.065	+
Mechanics & Materials	4.29	5	4.55	5	0.278	0
Thermal Fluid Systems	3.43	4	3.98	4	0.011	+
Manufacturing & Design	4.65	5	4.77	5	0.371	0
Programming& Computer Aided Design	4.57	5	4.25	4	0.015	-

C. *Academic Disciplines: Relevance*

Students felt that applied science, business, and mathematics were the most relevant to product development before and after the activity (median = 5). Students felt that political science (median = 2), social science (median = 3), and humanities (median = 3) were the least relevant to product development before the activity. Students felt that only political science was the least relevant to product development after the activity (median = 3). The relevance of business, humanities, social sciences, and political science increased (p-value 0.027, 0.002, ~0, 0.002 respectively). Out of these four NEAD, the relevance of social sciences had the largest increase and business had the smallest increase. These results are summarized in Table IV.

TABLE IV. ACCORDING TO YOU, HOW RELEVANT ARE THE FOLLOWING ACADEMIC DISCIPLINES TO THE SUCCESSFUL DEVELOPMENT, OPERATION AND USE OF THE PRODUCTS YOU LISTED PREVIOUSLY?

Survey Item	Pre		Post		P-value	Significance
	Mean	*Median*	*Mean*	*Median*		
Business	4.29	5	4.75	5	0.027	+
Humanities	2.96	3	3.84	4	0.002	+
Natural Science	4.02	4	4.27	4	0.400	0
Applied Science	4.45	5	4.66	5	0.358	0
Mathematics	4.37	5	4.43	5	0.810	0
Social Science	2.76	3	3.73	4	~0	+
Political Science	2.31	2	3.25	3	0.002	+

D. Academic Disciplines: Formation as Engineer

Students felt that business, applied science, mathematics, and political science were the most relevant to their formation as mechanical engineers before the activity (median = 4). Students felt that business, applied Science, mathematics, political science, and social science were most relevant to their formation as mechanical engineers after the activity (median = 4). Students considered humanities, natural science and social science to be least relevant to their formation as mechanical engineers before the activity (median = 2). Students considered humanities to be least relevant to their formation as mechanical engineers after the activity (median = 2). The relevance of social sciences increased (p-value ~0) while the relevance of political science decreased (p-value 0.012). These results are summarized in Table V.

TABLE V. ACCORDING TO YOU, WILL THE FOLLOWING ACADEMIC DISCIPLINES HAVE ANY IMPACT ON YOUR FORMATION AS A MECHANICAL ENGINEER?

Survey Item	Pre		Post		P-value	Significance
	Mean	*Median*	*Mean*	*Median*		
Business	3.51	4	3.48	4	0.836	0
Humanities	2.06	2	2.27	2	0.416	0
Natural Science	2.63	2	2.78	3	0.393	0
Applied Science	3.61	4	3.57	4	0.977	0
Mathematics	3.51	4	3.45	4	0.933	0
Social Science	2.59	2	3.45	4	~0	+
Political Science	3.86	4	3.45	4	0.012	-

E. Understanding of Role of Mechanical Engineer

The students showed a significant increase in their understanding of the role of a mechanical engineer (p-value 0.008). These results are summarized in Table VI.

TABLE VI. I HAVE A CLEAR UNDERSTANDING OF WHAT A MECHANICAL ENGINEER DOES.

Pre		Post		P-value	Significance
Mean	*Median*	*Mean*	*Median*		
4.84	5	5.45	6	0.008	+

VI. DISCUSSION AND FUTURE WORK

The activity showed high potential to increase students' excitement, awareness, and motivation towards integrating engineering areas of study and non-engineering academic disciplines (NEAD) through complex, real-world designs. Although students' excitement about different ME areas of study remained unchanged, the students showed a statistically significant increase in their understanding of the role of a mechanical engineer. Since the sample only included mechanical engineering students, it came with no surprise that the excitement about various ME areas of study remained unchanged, as students had an established familiarity with them.

One ME area of study that stood out was thermal fluid systems (TFS). TFS scored the lowest rating for excitement as well as perceived relevance to product development. Despite the lowest scores, there was a statistically significant increase in students' perceived relevance of TFS to product development. This further shows the success of the designed activity and guides the researchers to investigate how to strengthen the awareness of this area of study in future iterations. It is worth future investigation to determine what factors about this ME area of study make it less exciting to sophomore students. At the same time, any future iterations of the activity must include a careful selection of products that illustrate the contributions of this ME area of study. To better understand students' perspectives on why some areas of mechanical engineering, like TFS, are more or less interesting, a focus group of four students who completed the activity was conducted one year following the activity's completion. This data will be analyzed in the coming months.

Another unexpected trend observed was the statistically significant decrease in the perceived relevance of programming and computer-aided-design to product development, despite programming being an essential element of all the assigned innovations. This further guides the researchers to identify potential reasons for this decrease. Product selection may be a factor in this trend. For example, the mean perceived relevance of programming identified by the geothermal heat pump and ventilator teams increased, while that of the Honda Smart Home and pacemaker decreased. Interviews with mechanical engineering faculty will be conducted to develop a strategic list of innovations for which connections to all mechanical engineering areas of study will be more visible. The core success of the activity depends on the products chosen for investigation. Therefore, future work also involves analyzing trends in excitement and relevance, categorized by different innovations. The impact of the product selection on students' perceptions will be assessed in the coming months. This will further explain key strategies to select the right innovations for the activity.

In addition to impacting students' excitement and perceived relevance for ME areas of study, the activity showed significant success in positively impacting students' perception of NEAD. Often, engineering curricula is dense, technical, and isolated. Many of the course assignments simply focus on the respective course topics with little to no connections with other courses, let alone external academic disciplines. Majority of students do not get the chance to work in multidisciplinary teams either. This is partly due to the lack of time and space in curriculum and to the logistics challenges of integrating academic disciplines at a university [2]. However, to mimic the real world and to maximize students' professional preparedness, it is important to expose students to the connections between engineering and non-engineering disciplines. The results from this study supported the activity's ability to do so without demanding large amounts of time from the students or the instructor, and without any additional burden to the curriculum. To better understand professional outcomes desired by industry, including the ability to draw interdisciplinary connections, industry professionals will be interviewed in the coming months.

As outlined in the results there were statistically significant increases in the perceived relevance of business, humanities, social sciences, and political sciences to product development. Even though the other NEAD (applied sciences, natural science, and mathematics) did not see a statistically significant increase, the scores for their relevance remained high (medians > 4). Upon a review of the engineering curriculum at the university it was noted that students engage in applied sciences and mathematics during their freshman year and this study was conducted with sophomore students. Therefore, the perceived relevance of these NEAD begin at a high score and are unaffected by the activity itself. Although data showed an increase in the perception of four NEAD's relevance to product development, it only showed an increase in perception of social science's relevance to their formation as a mechanical engineer. In other words, although students had an increased understanding of the impact of business, political science, and humanities on product development, they did not seem to think that all of these NEAD impact their formation as an engineer. In fact, political science saw a decrease in relevance to formation as a mechanical engineer. This further guides the researchers and instructors to determine strategies for executing the activity in a way to highlight the role of all NEADs to significant extent. For instance, teams struggling with mapping social sciences were prompted to think about 'how would people use or perceive this product'. It may be argued that this prompt enabled them to make the connection between social sciences and their formation as an engineer. This leads the researchers to believe that a similar prompt could contribute to an increase in other NEAD's impact if it was given to the students. Further consultation with experts in NEAD will be conducted in future to determine prompts and questions that could be shared with students to facilitate an improvement in this area. Interviews with NEAD experts will also provide insight into the actual level of relevance of each NEAD to engineering to optimize students' takeaway from the activity. In other words, a question may be raised; *"are all academic disciplines always equally relevant?"*. To date, eight professors from the NEADs have participated in semi-structured interviews to provide feedback on the activity design, particularly regarding (a) provided area of study definitions, (b) quality of student generated connections, (c) ideal mapping and (d) prompts and questions to facilitate making connections. Future interviews will include discussions about actual level of relevance of the NEAD to engineering.

The activity showed significant potential to increase students' learning about integrating engineering areas of study and non-engineering academic disciplines through complex, real-world designs. The generated concept maps showed sufficient depth and detail to illustrate student' understanding of the application of ME areas of study and NEAD. Currently, detailed rubrics are being developed to objectively assess the concept maps to evaluate student learning. Once completed the student learning will be mapped to students' self-reported responses. This work also includes input from multiple experts and faculty members from various NEAD. To further enhance this body of work, industry professionals will be interviewed to optimize the activity's impact on professional preparedness. Retrospective pre-post essays completed by the students after the activity will also be analyzed to further optimize the activity as an education tool.

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VII. Conclusion

Overall, the activity was successful in improving students' perception of some areas of ME and NEAD's relevance to product development and students' formation as mechanical engineers. Being able to draw interdisciplinary connections between technical products and non-technical academic disciplines can be a valuable tool in enhancing students' interdisciplinary thinking, which is critical to academic and professional preparedness. Results from this study indicate that product decomposition and intra- and interdisciplinary concept mapping can help meet this goal. The improvement of students' understanding of the role of mechanical engineers was a significant success for early college students. This can positively impact students' subsequent ME courses and also improve their sense of belonging, thereby improving retention [28]. The outcome of this research will be a validated, optimized activity, associated assessments and rubrics for interdisciplinary engineering design education. The activity is adjustable to instructor needs and can be shortened or extended to fill available instruction time. While a proposed list of technical innovations is provided, student curiosity could be further supported by allowing students to research and select an innovation of their choosing, contingent on it meeting the standard for innovation set forth. The ease of adoption, the positive impact on student learning and attitudinal factors, and the adaptability and flexibility of this activity will make it a fruitful contribution to the field of engineering education.

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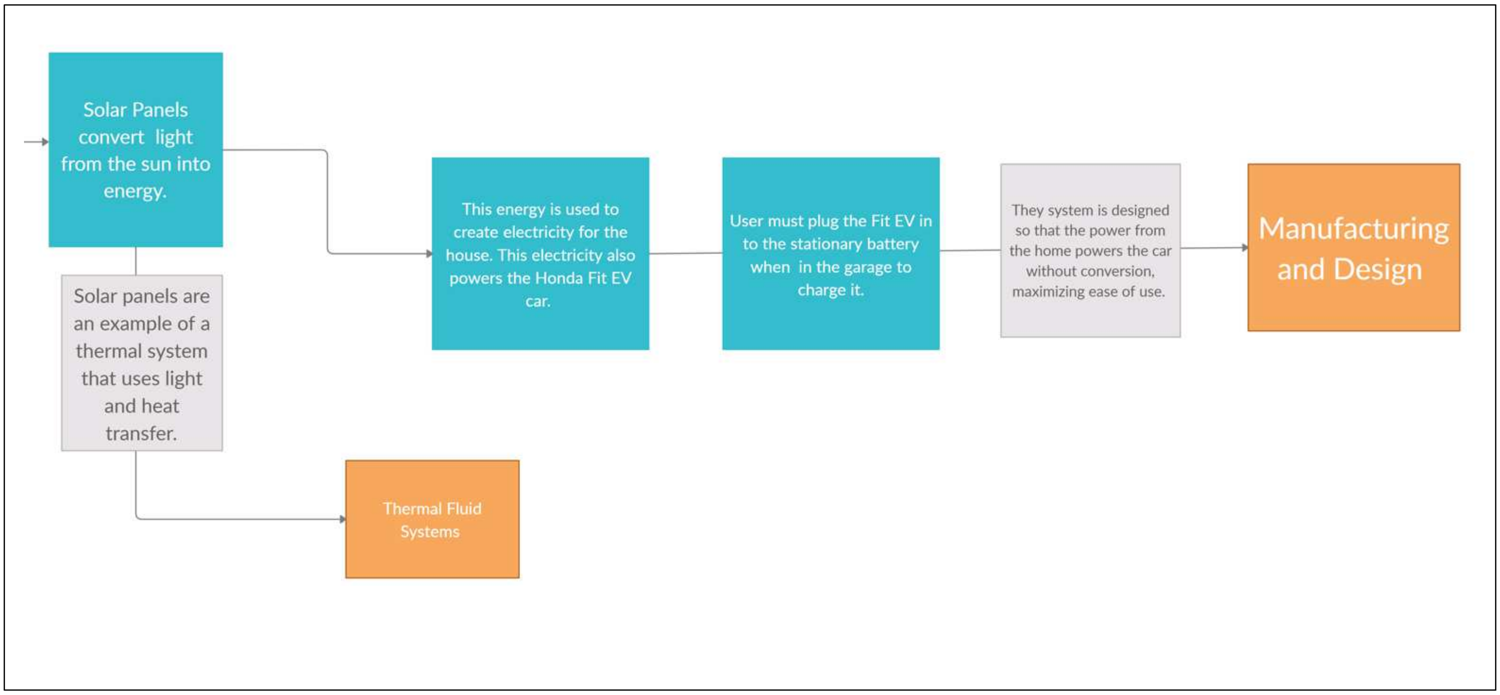

Fig. 1. Mechanical Engineering Areas of Study Sample Concept Map

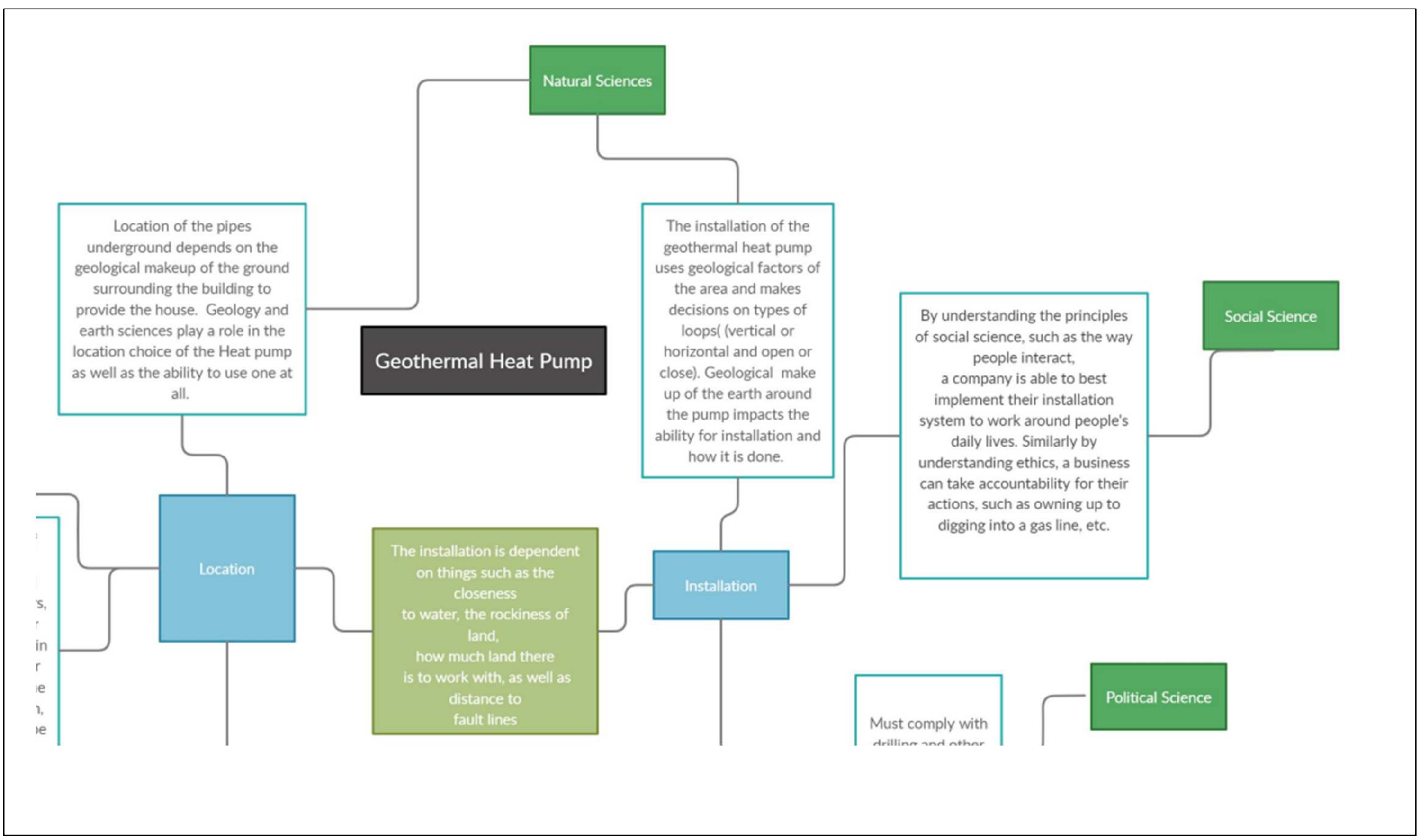

Fig. 2. NEAD Sample Concept Map